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Very High Efficiency Dedicated Outside Air System:

Equipment and Design Best Practices for Optimal Energy Efficiency

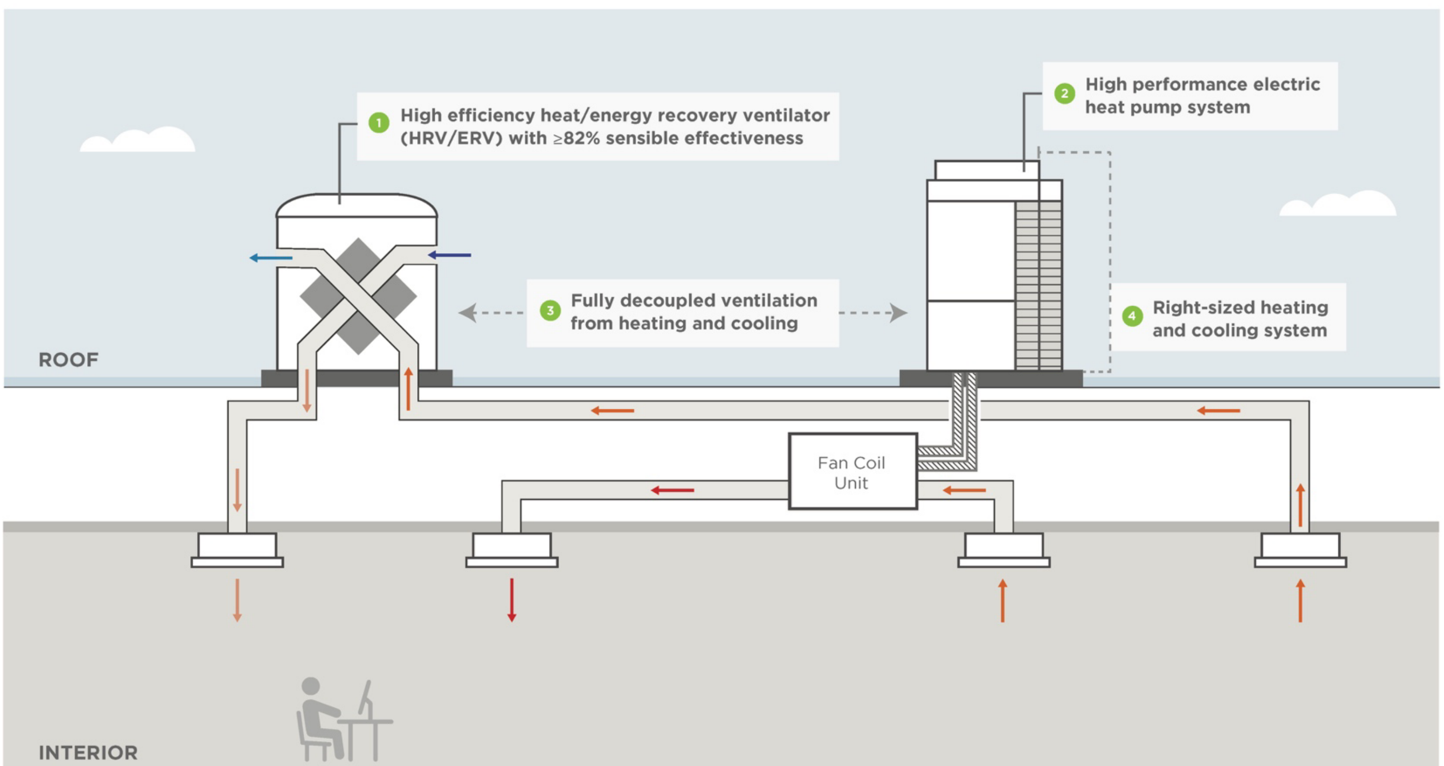
SYSTEM REQUIREMENTS | ADDITIONAL DESIGN RECOMMENDATIONS | HRV/ERV REQUIREMENTS & PRODUCTS | HEATING/COOLING EFFICIENCY REQUIREMENTS

INTRODUCTION

The following system definition and design recommendations provide guidance to manufacturers, designers and specifiers regarding the key components of a very high efficiency dedicated outside air system (or very high efficiency DOAS). Developed and refined over several years of research, market analysis, and demonstration project installations, this system approach improves indoor-air quality and occupant comfort, and decreases energy use, compared to a conventional rooftop packaged HVAC system.

For more information, including research findings and case studies, visit: betterbricks.com/solutions/very-high-efficiency-dedicated-outside-air-systems.

[Figure 1: Diagram featuring the key components of very high efficiency DOAS]



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SYSTEM REQUIREMENTS

The following System Requirements detail the key components of systems that qualify as very high efficiency DOAS.

1) High Efficiency Heat/Energy Recovery Ventilation (HRV/ERV)

- Prescriptive Requirements Path: Equipment listed on the Compliant Products Lists (CPL)*

OR

- Design Requirements Path: Demonstrate compliance with Design Requirements column of *HRV/ERV Minimum Requirements Table* in Appendix A with equipment selected at design conditions using AHRI 1060 certified software with HRV/ERV sensible effectiveness ≥ 82%*

*See *HRV/ERV Minimum Requirements Table* in Appendix A for detailed CPL requirements and current qualified equipment.

2) High-Performance Electric Heating/Cooling Equipment

Allowable Heating/Cooling Equipment Types
Multi-zone or single zone air-source split system heat pump (i.e., mini-split or ducted/ductless multi-zone), VRF air-source heat pump, air-to-water heat pump,[1] heat pump or heat recovery chiller, ground-source or ground-water source heat pumps.

Exception: Water-source heat pumps admissible only if existing in the building and not being replaced.[2]
Exception: Multi-family and lodging buildings may use the following alternate heating sources:

- Packaged terminal heat pumps that meet minimum efficiency requirements in Appendix B.
- Electric resistance heat in PHIUS certified buildings in spaces where no cooling is provided.

Heating/Cooling System Efficiency
All heating/cooling equipment must meet current ENERGY STAR® minimum efficiency requirements, or meet requirements as defined in the *Heating/Cooling Equipment Minimum Efficiency Requirements* detailed in Appendix B.

Effective 1/1/2023, air-source heat pumps must comply with ENERGY STAR® Light Commercial HVAC Version 4.0 cold climate heat pump requirements.

3) Decoupled Ventilation Design

Best Practice: Fully decoupled system design	Good Practice: Partially decoupled system design
Ventilation air must be delivered directly to the occupied space, with ventilation and heating/cooling system fans controlled independently[3]. The ventilation duct system must meet the following requirements: • Except where site conditions limit or restrict this approach, maintain at least half the length of the space between ventilation supply air outlet and exhaust/return grille to avoid short-circuiting. • Separate ventilation supply outlets are required for all spaces, and they must include either a ducted return or a non-ducted return path with the free area sized so that air velocity does not exceed 300 FPM. Note that a plenum return is acceptable.	Ventilation and heating/cooling system fans must be controlled separately[3]. Ventilation air from the HRV/ERV unit is supplied to each occupied space, either directly through a dedicated supply outlet or through heating/cooling ductwork when the ventilation supply air is delivered downstream of the terminal heating/cooling coils.

4) Right-Sized Heating/Cooling

Best Practice	Good Practice
A right-sized heating/cooling system is supported by load calculations and uses no greater than 10% safety factors.	Right-sized heating/cooling system is supported by load calculations and uses no greater than 20% safety factors.

[1] *Air-to-water heat pump may be used with various downstream terminal units. Terminal unit options may include chilled beams, 4-pipe fan coil units with ECM fan motors, or radiant heating/cooling systems.*
[2] *Water-source heat pumps are excluded because they typically use a fossil-fuel boiler as a central heating source.*
[3] *Exception: Systems using active chilled beams.*

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ADDITIONAL DESIGN RECOMMENDATIONS

When fully implemented, the following additional design recommendations yield a best-in-class HVAC system. Designers are encouraged to consider whether each design recommendation below is beneficial to a given project and implement as appropriate.

HRV/ERV Design

HRV/ERV Ductwork Design	Added Value
Consider slightly oversizing ventilation supply and return ductwork. Doing so allows for periodic increases in ventilation supply air. Increasing ventilation air allows for more effective free cooling during night purges, and can be beneficial in a variety of circumstance, including temporary spikes in occupancy or in planning for future expansion. Larger ductwork also results in lower system static pressure to reduce the system's overall fan power. Best practices for minimizing DOAS fan power include incorporating localized ventilation units and sizing ventilation ductwork to no more than 0.08 inches water gauge pressure loss per 100 feet of straight duct.	As demonstrated by a recent study,[4] increased ventilation flexibility is a very effective way of mitigating the risk of viral transmission in buildings, which can be achieved with a relatively small upfront cost of increased ductwork sizing. Additionally, energy modeling shows that reducing system fan power by 54% can yield up to 17% annual HVAC energy savings in climate zone 4C.

Variable Speed HRV/ERV Fan Controls	Added Value
HRV/ERV should include variable speed fans, with inputs capable of controlling fan speed based on time-of-day scheduling, and inputs for CO_2 and duct static pressure at a minimum.[5]	Variable fans allow for more efficient fan operation, easier startup and commissioning, and allows for varying ventilation levels when appropriate.

Heat Recovery Bypass Control Capabilities	Added Value
Include through use of variable damper control or wheel speed control.[6]	Heat recovery bypass allows for free cooling or night purges to offset mechanical cooling when outside air temperature is suitable.

Filters	Added Value
MERV 13 filters on outside air intake and MERV 8 filters on exhaust/return airstreams prior to the heat exchange medium.	Improved filtering capabilities can help to optimize indoor air quality by reducing infiltration of outdoor air contaminates such as pollen, smoke, and other pollutants.

HRV/ERV Supplemental Heating/Cooling	Added Value
In marine climates, consider excluding supplemental heating/cooling in the ventilation unit. Case studies have shown that this system design's required sensible effectiveness allows for comfortable ventilation supply air temperatures without additional tempering.	Eliminating supplemental heating/cooling reduces the upfront cost and control complexity of the HRV/ERV unit. This increases the cost-effectiveness of the entire system.

[4] *COVID-19 Risk Reduction Strategies and HVAC System Energy Impact*, Northwest Energy Efficiency Alliance, et. al., https://betterbricks.com/resources/covid-19-hvac-risk-reduction-strategies.
[5] Input for CO_2 and duct static pressure may be accomplished with integral sensors, auxiliary third-party sensors, or capability to receive 0-10 mV (or similar) signal from BMS, and respond accordingly.
[6] Heat recovery bypass control allows for variable operation that avoids heat exchange when desirable.

HRV/ERV Sizing	Added Value
Consider selecting HRV/ERV units at 30% below peak airflow capacity to allow for increased airflow during high-occupancy periods and future increased occupancy.	Allows for increasing ventilation levels when deemed appropriate, such as during pandemic operation, for night purge cycles, or during periods of high occupancy. Oversizing the HRV/ERV also increases energy recovery effectiveness and improves fan efficacy.

Outdoor Installation	Added Value
Outdoor HRV/ERV units should include casing insulation ≥ R-8 and gasketed seams and doors.	Minimizes casing heat loss in DOAS equipment installed outdoors.

Heating/Cooling System Design

Heating/Cooling System Fan Operation	Added Value
Cycle heating/cooling system fans off when there is no call for heating or cooling.[7]	Cycling fans reduces energy consumption when the space is not being heated or cooled.

Integral Refrigerant System Heat Recovery	Added Value
Analysis of past projects show that integral refrigerant heat recovery is often not cost-effective. Designers are encouraged to be aware of this tendency when selecting a variable refrigerant flow (VRF) system and carefully consider zoning plans (e.g., core or perimeter) to ensure effective use of the VRF's heat recovery feature.	Evaluating whether VRF refrigerant heat recovery is necessary and omitting when possible will help ensure the cost-effectiveness of the HVAC system.

Heating/Cooling System Sizing	Added Value
When using the very high efficiency DOAS approach, typical HVAC system sizing estimates are no longer feasible. Case studies have shown that typical sizing estimates don't account for the high efficiency heat recovery of the HRV/ERV, and therefore result in grossly oversized heating/cooling systems. These case studies have also demonstrated that the following sizing guidelines are achievable for typical office buildings in the Northwest region: o Climate Zone 4C: no less than 750 sq.ft./ton of system cooling capacity. o Climate Zone 5 & 6: no less than 600 sq. ft./ton of system cooling capacity.	Careful right-sizing of the heating/cooling system that accounts for the high efficiency heat recovery allows heating/cooling equipment to cycle less frequently and improves the first cost of the overall system.

Construction/Installation

Commissioning	Added Value
The commissioning agent should functionally test equipment installation, all dynamic control components and associated sequences of operation. The commissioning agent should also observe and verify ventilation system air balancing and duct leak testing. They should then make their report available to the system operator and building owner.	Commissioning helps ensure that all components and the system as a whole operates as designed.

[7] Exception: Systems using active chilled beams or when space heating/cooling system fan power is less than 0.12 W/cfm.

HRV/ERV Ductwork Insulation and Sealing	Added Value
Insulation of ventilation ductwork should follow these guidelines: o Tempered air ducts (HRV/ERV supply/return) installed exterior to the building: R-12. o Tempered air ducts (HRV/ERV supply/return) installed in unconditioned spaces: R-8. o Tempered air ducts (HRV/ERV supply/return) installed in conditioned spaces: none. o Outside air (entering HRV/ERV) and exhaust air (leaving HRV/ERV) ducts installed in conditioned spaces: R-16. o Consider sealing existing ductwork used as ventilation supply or return/exhaust to SMACNA Seal Class B standards where accessible, or if delivering greater than 500 CFM at design conditions. Then insulate ventilation supply and exhaust as per relevant code requirements for heating and cooling ductwork.	Duct insulation prevents condensation in conditioned spaces and energy losses in unconditioned spaces. Sealing contributes to indoor air quality by ensuring that adequate ventilation air is delivered to all spaces.

Startup and Testing, Adjusting, Balancing (TAB)	Added Value
The manufacturer (or a manufacturer approved technician) should provide startup of HRV. Consider requiring TAB of the entire HVAC system (including ventilation system airflow verification), with the following TAB conditions: o Air at each diffuser and heating/cooling system air handler tested and balanced to within +/- 10% (or 5 CFM, whichever is greater) at design flow.[8] o HRV/ERV system airflow tested and balanced to within +/- 5% of design airflow at HRV unit.[9]	Ensures system is installed and operates as designed.

Other Considerations

Energy Modeling	Added Value
Conventional energy modeling practices may misrepresent very high efficiency DOAS energy performance. Most hourly simulation tools do not support explicit modeling of the system's components, making modeling workarounds necessary. Workarounds can include fan power adjustments, post-processing requirements and control system adjustments.	Energy models can be used to demonstrate life cycle savings associated with a very high efficiency DOAS System. These may allow for custom energy savings incentives outside of those offered through the VHE DOAS Program. Contact your local utility for details.

[8] *TAB technician should use a flow hood measuring accurately down to 10 cfm, for both supply and exhaust airflows in a typical ventilation system.*
[9] *This is accomplished using reliable duct traverse at HRV unit discharge, or the manufacturer's on-board control output values.*

APPENDIX A: HRV/ERV MINIMUM REQUIREMENTS AND COMPLIANT PRODUCTS

HRV/ERV equipment can meet Core VHE DOAS System Requirements in one of two ways. Equipment can satisfy the Prescriptive Requirements listed in the left column below, in which case they will be listed on the Compliant Products List (CPL) on the next page. Alternatively, equipment can be selected at project design conditions to meet all Design Requirements listed in the right column below.

Minimum Requirements

<table>
<tr><th colspan="3">Table A1: Compliant Heat/Energy Recovery Ventilator (HRV/ERV)</th></tr>
<tr><th>Prescriptive Requirements (i.e., CPL)</th><th>- OR -</th><th>Design Requirements</th></tr>
<tr><td colspan="3">HRV/ERV thermal efficiency</td></tr>
<tr><td colspan="2">• Passive House Institute (PHI) certified, OR
• Minimum 82% Sensible Effectiveness of heat exchanger (HX) according to AHRI 1060-2018 certified software when selected at AHRI 1060-2014 winter conditions[10] at 75% of nominal airflow[11].</td><td>• Minimum HRV heat exchange of 82% sensible effectiveness as selected using AHRI 1060-2018 certified software at heating and cooling design temperatures and airflows.</td></tr>
<tr><td colspan="3">ERVs meeting the above minimum sensible effectiveness are allowed and may be preferable in some designs to offset indoor humidity loads and decrease defrost energy requirements.</td></tr>
<tr><td colspan="3">HRV/ERV fan efficacy</td></tr>
<tr><td colspan="2">• PHI certified, OR
• Minimum 1.3 cfm/Watt at 0.5” w.g. external static pressure at 75% of rated air flow[12]. Variable speed supply and exhaust fans are required.</td><td>• Minimum 1.3 cfm/Watt at design operating conditions[13]. Variable speed supply and exhaust fans are required.</td></tr>
<tr><td colspan="3">Cross-flow leakage/Exhaust Air Transfer Ratio (EATR): Less than 3%.</td></tr>
<tr><td colspan="2">• PHI certified; internal leakage must be <3%, OR
• AHRI 1060-2018, the EATR must be less than 3% when selected at 100% of nominal airflow, at both 0 in w.g. and 0.5 in w.g. differential pressure using AHRI 1060 certified software (or as verified by third party testing).</td><td>• AHRI 1060-2018 certified products, EATR must meet the specified requirement based on AHRI Certified Selection Software when selected at design airflows and external static pressures.</td></tr>
<tr><td colspan="3">Minimum HRV/ERV Capabilities:</td></tr>
<tr><td colspan="3">Ventilation unit shall provide a means for heat recovery defrost control if climate conditions warrant (recirculation of return air for defrost control is prohibited). Where electric resistance heating is provided as a means of defrost control or supplemental tempering, it must include modulating (SCR) control.</td></tr>
</table>

[10] AHRI 1060-2014 winter conditions: 35°F DBT, 35°F WBT (OA); 70°F DBT, 58°F WBT (RA) at 75% and 100% of rated airflow. Supply and exhaust airflows shall be balanced to within 1.5%, in accordance with AHRI 1060-2014 requirements.

[11] Independent third-party test results demonstrating sensible effectiveness when tested in accordance with the specified conditions (per ASHRAE Standard 84) is acceptable in lieu of AHRI 1060-2018 certified software results.

[12] Fan energy as measured during certification or application rating testing as per AMCA 210 test standards.

[13] Fan efficacy shall be determined by the following equation at design operating conditions: $\frac{Supply\ Fan\ CFM}{Total\ Fan\ Power\ (Supply\ Fan\ Watts + Exhaust\ Fan\ Watts)}$, *with total fan power rated per AMCA 210/211 test standards.*

[REVISED OCTOBER 2022]

Compliant Products

The following HRV/ERV equipment is compliant with the prescriptive requirements path in table A1: Minimum Requirements above. Models listed do not indicate compliance with comprehensive very high efficiency DOAS requirements.

Table A2: HRV/ERV Compliant Products

Manufacturer	Model #	HRV/ERV	Nominal CFM
Greenheck	ERV-20-15L[1]	ERV	1400
Greenheck	ERVe-20-15L[1]	ERV	1400
Greenheck	ERV-20-30L[1]	ERV	2000
Greenheck	ERVe-20-30L[1]	ERV	2000
Greenheck	ERVe-45-30L[1]	ERV	4200
Oxygen8	Ventum H05	HRV	600
Oxygen8	Ventum H10	HRV	1000
Oxygen8	Ventum H15	HRV	1150
Oxygen8	Ventum H20	HRV	1530
Oxygen8	Ventum H25	HRV	2250
Oxygen8	Ventum H30	HRV	3000
SEMCO	EP-03[1]	ERV	1700
SEMCO	EP-05[1]	ERV	3000
SEMCO	EP-09[1]	ERV	5100
SEMCO	EP-13[1]	ERV	7900
SEMCO	EP-18[1]	ERV	10900
SEMCO	EP-24[1]	ERV	14300
SEMCO	EP-28[1]	ERV	17000
SEMCO	EP-35[1]	ERV	21100
SEMCO	EP-43[1]	ERV	25700
SEMCO	EP-46[1]	ERV	28000
SEMCO	EP-56[1]	ERV	33600
SEMCO	EP-70[1]	ERV	42200
Swegon	Gold RX 05	HRV	840
Swegon	Gold RX 07	HRV	1430
Swegon	Gold RX 08	HRV	1530
Swegon	Gold RX 11	HRV	2200
Swegon	Gold RX 12	HRV	2370
Swegon	Gold RX 14	HRV	3530
Swegon	Gold RX 20	HRV	3570
Swegon	Gold RX 25	HRV	4730
Swegon	Gold RX 30	HRV	4730
Swegon	Gold RX 35	HRV	7600
Swegon	Gold RX 50	HRV	10670
Swegon	Gold RX 05 MTE	ERV	840

Table A2: HRV/ERV Compliant Products

Manufacturer	Model #	HRV/ERV	Nominal CFM
Swegon	Gold RX 07 MTE	ERV	1430
Swegon	Gold RX 08 MTE	ERV	1530
Swegon	Gold RX 11 MTE	ERV	2200
Swegon	Gold RX 12 MTE	ERV	2370
Swegon	Gold RX 14 MTE	ERV	3530
Swegon	Gold RX 20 MTE	ERV	3570
Swegon	Gold RX 25 MTE	ERV	4730
Swegon	Gold RX 30 MTE	ERV	4730
Swegon	Gold RX 35 MTE	ERV	7600
Swegon	Gold RX 40 MTE	ERV	7870
Swegon	Gold RX 50 MTE	ERV	10670
Swegon	Gold RX 60 MTE	ERV	10710
Swegon	Gold RX 70 MTE	ERV	14400
Swegon	Gold RX 80 MTE	ERV	14670
Tempeff	RG 1000	HRV	1000
Tempeff	RG 1500	HRV	1500
Tempeff	RG 2000	HRV	2000
Tempeff	RG 3000	HRV	3000
Tempeff	RG 4000	HRV	4000
Tempeff	RG 5500	HRV	5500
Tempeff	RG 6500	HRV	6500
Tempeff	RGL 1000	HRV	1000
Tempeff	RGL 1500	HRV	1500
Tempeff	RGL 2000	HRV	2000
Tempeff	RGL 3000	HRV	3000
Tempeff	RGL 4000	HRV	4000
Tempeff	RGL 5500	HRV	5500
Tempeff	RGL 6500	HRV	6500
Ventacity	VS1000 RTh	HRV	1000
Ventacity	VS1000 RTe	ERV	1000
Ventacity	VS3000 RTh	HRV	3000
Ventacity	VS3000 RTe	ERV	3000
Ventacity	VS1200CMh	HRV	1200
Ventacity	VS900CMh	HRV	900
Ventacity	VS250CMh	HRV	250

Compliance Notes

[1] Compliant unit must include energy recovery purge section to minimize exhaust air leakage. Unit must be selected to operate at greater than 0 in. wg. differential pressure between outside air and exhaust air pathways.

[2] Residential size equipment (<300 cfm) that is PHI Certified can be compliant for multi-family in-unit applications, if it meets all other criteria.

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APPENDIX B: HEATING/COOLING EQUIPMENT MINIMUM EFFICIENCY REQUIREMENTS

Where applicable, allowable space heating/cooling equipment shall meet ENERGY STAR minimum efficiency requirements. Where ENERGY STAR does not apply, the minimum efficiency requirements in Table B1, below, apply.

Table B1: Allowable Heating/Cooling Equipment and minimum efficiency requirements

Heating/Cooling Equipment	Minimum Heating Efficiency	Minimum Cooling Efficiency	Notes
Mini-split or ductless multi-zone heat pump (<65 kBtu/hr.)[14]	9.5 HSPF, or 7.8 HSPF2	16 SEER, or 15.2 SEER2	HSFP2 and SEER2 are optional until January 1, 2023[15].
Air-source VRF (≥65 kBtu/hr. and <135 kBtu/hr.)[16] without heat recovery	3.4 COP (47°F)	17.4 IEER	Applies to both ducted and non-ducted systems.
Air-source VRF (≥65 kBtu/hr. and <135 kBtu/hr.[17] with heat recovery	3.4 COP (47°F)	17.2 IEER	Applies to both ducted and non-ducted systems.
Air-source VRF (≥135 kBtu/hr. and <240 kBtu/hr.)[17] without heat recovery	3.3 COP (47°F)	16.4 IEER	Applies to both ducted and non-ducted systems.
Air-source VRF (≥135 kBtu/hr. and <240 kBtu/hr.)[17] with heat recovery	3.3 COP (47°F)	16.2 IEER	Applies to both ducted and non-ducted systems.
Air-source VRF (≥240 kBtu/hr.)	3.2 COP (47°F)	16.2 IEER	Applies to both ducted and non-ducted systems.
Air-to-water heat pump	1.7 COP		@ 5°F dry bulb and LWT of 110°F
Ground-source heat pump[17]	3.6 COP[19] at 32°F EWT	17.1 EER[20] at 77°F EWT	Closed loop water-to-air.
Groundwater-source heat pump[17]	4.1 COP[19] at 50°F EWT	21.1 EER[20] at 59°F EWT	Open loop water-to-air.
Heat recovery or heat pump chiller	1.7 COP	9.7 EER 15.9 IPLV	COP @ 5°F dry bulb and LWT of 110°F EER and IPLV rated per AHRI 550/590
Packaged Terminal Heat Pump (<9100 Btu/hr.)[18]	3.6 COP	13 EER	Allowed in multi-family and lodging occupancies only.
Packaged Terminal Heat Pump (9100 Btu/hr. to 10800 Btu/hr.)[18]	3.5 COP	12 EER	Allowed in multi-family and lodging occupancies only.
Packaged Terminal Heat Pump (10801 Btu/hr. to 12600 Btu/hr.)[18]	3.4 COP	11.6 EER	Allowed in multi-family and lodging occupancies only.
Packaged Terminal Heat Pump (>12600 Btu/hr.)[18]	3.3 COP	10.4 EER	Allowed in multi-family and lodging occupancies only.
Electric resistance heat	1.0 COP	Not allowed	Allowed only in PHIUS certified buildings in spaces with no cooling.

[14] *ENERGY STAR Central Air Conditioner and Heat Pump Equipment Eligibility Criteria Version 6.1*

[15] *HSPF and SEER are determined in accordance with 10 CFR 430 Appendix M and HSPF2 and SEER2 are determined in accordance with Appendix M1. Appendix M1 of 10 CFR 430 test procedure and ratings, as issued by the U.S. Department of Energy (82 FR 1426, January 2017) are not mandatory until January 1, 2023.*

[16] *ENERGY STAR Light Commercial HVAC Version 3.1 Program Requirements*

[17] *ENERGY STAR Program Requirements Product Specification for Geothermal Heat Pumps Eligibility Criteria Version 3.2*

[19] *Multi-stage models qualify using the following calculation: EER = (highest rated capacity EER + lowest rated capacity EER) / 2*

[20] *Multi-stage models qualify using the following calculation: COP = (highest rated capacity COP + lowest rated capacity COP) / 2*

[18] *Packaged Terminal Heat Pump performance shall be tested and certified to AHRI Standard 310/380. Minimum efficiency levels established in accordance with DOE Zero Energy Home Guideline.*